

The Metal's Edge

The Rare Earth Dilemma: China's Market Dominance

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This is the final article in the three-part series on rare earth elements. The first focused on the role of rare earth elements in energy security; the second, on the environmental implications of rare earth mining and production.

Rare earth elements (REE) play a key role in

developing technology today, yet few people have ever heard of them or truly understand their significance. REEs were first discovered in 1787 by Lieutenant Carl Axel Arrhenius, a Swedish army officer. Since then there has been a great deal of interest in their chemical properties and potential uses. If it were not for REEs, technology would be vastly different. REEs have diverse chemical, nuclear, metallurgical, magnetic, optical, and electrical properties that have led scientists to pursue an ever increasing variety of applications for them. They are vital to hundreds of high tech applications including green technologies and critical military technologies.

The U.S. paved the way for many of today's modern technologies that China is now capable of exploiting. Part of that effort has entailed scientists focusing on and dissecting the properties and uses of REEs. From about the 1940s to the 1990s, REEs attracted great interest in both the U.S. and China's academic and scientific communities. Today, however, there are only a small handful of scientists who truly focus on REEs in the U.S. China, on the other hand, could be setting itself up to become a superpower in technological innovation through its near monopoly and its vast efforts in research and development of REEs.

During the 1990s, the full value of China's rare earth industry began to take root. In 1992, during his visit to Bayan Obo, China's largest rare earth mine, Chinese leader Deng Xiaoping declared, "There is oil in the Middle East; there is rare earth in China." Seven years later Chinese president Jiang Zemin wrote, "Improve the development and application of rare earth, and change the resource advantage into economic superiority." In 1996, Chinese authors Wang Mingjin and Dou Xuehong, both from the China Rare Earth Information Center at the Baotou Research Institute of Rare Earth in Inner Mongolia, published a paper called *The History of China's Rare Earth Industry*. In it they wrote, "China's abrupt rise in its status as a major

producer, consumer, and supplier of rare earths and rare earth products is the most important event of the 1980s in terms of development of rare earths."

China knew what it had even before the 1990s. In the 1950s the Bayan Obo mine was built and operated as the iron ore base of the Baotou Iron and Steel Company. In the late 1950s, China began recovering rare earths during the process of producing iron and steel. Since the 1960s, China has emphasized maximizing the use of Bayan Obo, which is located in Inner Mongolia, 80 miles north of Baotou. This effort included employing people to find more effective ways to recover the rare earths. Along with trying to improve separation techniques, China also began other research and development efforts. In 1963, they established the Baotou Research Institute of Rare Earths.

There are two "state key laboratories" in China, the State Key Laboratory of Rare Earth Materials Chemistry and Applications, which is affiliated with Peking University in Beijing; and the State Key Laboratory of Rare Earth Resource Utilization, in Changchun, in the Northern province of Jilin.

Globally, there are two journals dedicated to the research and study of REEs. Both of these journals, which are available in English, are from China. They are the *Journal of Rare Earth* and the *China Rare Earth Information Journal* (CREI), both put out by the Chinese Society of Rare Earths. The Chinese Society of Rare Earths was founded in 1980 and it comprises tens of thousands of registered scientific and technical researchers of rare earths. According to the Society of Rare Earths website, there are more than 100,000 registered experts. However, approximately one quarter to one third of these "registered experts" are likely administrative personnel. The number of U.S. scientists devoted to the research and study of REEs today pales in comparison to the vast number of scientists in China.

According to a news segment, which aired in June 2010 on the PBS Newshour, Mark Smith, Chief Executive Officer of Molycorp, which owns and operates California's Mountain Pass mine, the only operating rare earth mine in North America, pointed out that America was once the number one country in the world when it came to the research, use, development, and application of rare earths. Now, however, "We have completely dropped the ball in that regard. It's all gone to China," stated Smith.

During a 16 March 2010 hearing before the U.S. House of Representatives Committee on Science and Technology, Smith pointed out, "I have 17 scientists and engineers that are competing with over 6,000 Chinese scientists."

One could argue that the research and development efforts of REEs has mirrored the industry. Through most of the second half of the 20th century, the Mountain Pass mine was the largest rare earth mine in the world. During the time frame in which Mountain Pass was in full production, American students and professors were greatly interested in learning about the properties of these unique materials. Their efforts led to ground breaking uses for REEs both commercially and militarily.

While China has completely embraced rare earth and gained a foothold in the industry, U.S. academic interest in rare earth seems to have waned. This lack of interest, however, is not likely due to a lack of resources, but to what Karl Gschneidner, Jr., an Anson Marston Distinguished Professor in the Department of Materials Science at Iowa State University, says is a student tendency to gravitate more toward "what's hot." They want to make the most impact both as students and later in their careers. As needs arise for new technologies, such as developing biofuels, student interest tends to shift as they strive to stay on top of the latest trends.

Today Gschneidner, who has been studying REEs since 1952, is one of only a handful of American scientists focusing his efforts in the field today. He is most renowned for his work on magnetic materials, in particular magnetic refrigeration, which is a revolutionary, energy efficient, and environmentally friendly cooling technology.

Up until the mid 1990s, Gschneidner taught a course dedicated to REEs. The course, which was called Chemical and Physical Metallurgy of Rare Earths, included a thorough lesson on the history of REEs, a discussion of the ores and how they are processed, and a study of rare earth properties and behaviors. "I used to have a pretty good group of students who would take that course," Gschneidner said. The course has not been taught for the past 15 years. However, Gschneidner continues to press on with his own research.

While U.S. academic circles seem to have lost interest in REEs, China has forged ahead with its government backed research and development efforts and is now producing over 95 percent of the world's rare earth supplies. Meanwhile, the country has been dramatically cutting back its export quotas over the past several years, making REEs in their raw form (oxides), less and less accessible. Many analysts see this as China's way to pull global manufacturing efforts into the country.

China is putting itself at an economic and strategic advantage by increasing its role in the manufacturing supply chain. Whereas China simply started out as an exporter of rare earth mineral concentrates, the country has been gradually moving its way toward dominating the manufacturing supply chain. This is good for China because it provides more jobs, helps to improve the economy, and can provide access to important technology, some of which might be proprietary.

In today's world of energy security and environmental concerns, magnetic technology rates as the most important use of REEs due to its many uses in green technologies and military applications. The two primary rare earth magnets are the samarium-cobalt (SmCo) magnet and the neodymium-iron-boron (NdFeB) magnet. The SmCo magnet is able to retain its magnetic strength at elevated temperatures. Because of its thermo-stability, this type of magnet is ideal for special military technologies. These technologies include precision guided munitions—missiles and "smart" bombs and aircraft.

The NdFeB magnet came about in the 1983 when scientists from General Motors and Hitachi each found that NdFeB had superior permanent magnetic properties, and submitted applications for patents. A battle ensued and both companies came to an agreement that split the rights to the discovery.

GM needed the magnets for its vehicles and in 1986 the company established a new division to produce the NdFeB magnets. They called the division Magnequench. In 1995 two Chinese groups, the Beijing San Huan New Materials High-Tech Inc. and China National Non-Ferrous Metals Import & Export Corporation, joined forces with Sextant Group Inc, an American investment firm founded by Archibald Cox, Jr., and tried to acquire Magnequench. The purchase was reviewed by the U.S. government and finally went through after China agreed to keep Magnequench in the United States for at least five years. Magnequench was located in Anderson, Indiana.

The day after China's deal to keep Magnequench in the United States expired in 2002, the entire operation, along with all the equipment, disappeared. All employees were laid off and the company moved to China. At the time, it seemed that no one really cared. Today, however, "they are all sorry about that mistake," Gschneidner points out. "As the business went, technology went."

In less than one decade, the permanent magnet market experienced a complete shift in leadership. Whereas in 1998, 90 percent of the world's magnet production was in the United States, Europe, and Japan, today, rare earth magnets are sold almost exclusively by China or using Chinese rare earth oxides.

According to the Government Accountability Office, it could take up to 15 years for the United States to reestablish its rare earth supply chain. Starting up a rare earth mining and processing venture is a time-consuming and highly complex process. After discovering a potential site and conducting a feasibility study, this type of mining operation requires permits, financing, building of infrastructure (including roads, railways, etc...), the acquisition of mining technology, transportation for the materials available, and so on. All of these steps could easily take up to ten years or more to accomplish.

Currently, outside of China, there are several mines striving to become fully operational. These include Mount Weld (owned by Lynas Corp), located in Australia; Mountain Pass (owned by Molycorp Minerals); Thor Lake (owned by Avalon) and Hoidas Lake (owned by Great Western), both located in Canada; and Steenkampskraal (owned by Rareco, a division of Great Western), located in South Africa. Mountain Pass and Mount Weld are scheduled to begin full production within the next one to two years if all runs smoothly.

Provided the Mountain Pass project stays on track, it may be enough to sustain many of the U.S. domestic needs for REEs. While the United States still leads in technological innovation, China's manufacturing capabilities and vast efforts in research and development could prove to become a major challenge.

The rest of the world was seemingly asleep as China grew to become a goliath in the rare earth industry. It took the rest of the world nearly 20 years to suddenly wake up to the realization that the future of high technology could be in the hands of this one supplier (China) if we don't act now. While there may be ample REEs in the Earth's crust, the challenge is in locating reserves worth mining and putting into place the infrastructure and processes necessary to mine and process them. Yet, despite Western efforts to open up other avenues to other REE resources, China's momentum in research and development and production will be a tough act to follow.

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